**APPLYING ANALYTIC HIERARCHY PROCESS (AHP) TO SELECT CLIMATE CHANGE ADAPATION METHODS IN AGRICULTURAL SECTOR: LITTERATURE REVIEW**

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| ABSTRACT  |
| *According to COP22 statement, climate change adaption now is the concern of not only one individual but also of whole society. Since climate change issue is a multidimensional problem, decision-making in climate change adaption is the complex process. In this paper, we analysis the advantages and disadvantages of three main group of decision-support tools, namely: Expert preference, Monetary valuation and Multi-criteria analysis (MCA). Paper recommends MCA in general and AHP in particular as an effective tool to compensate the disadvantage of other techniques as well as to overcome the challenges and requirements from climate change adaption decision making process.****Keywords: Climate change, AHP, MCA, Monetary valuation, Expert preference***  |

1. **INTRODUCTION**

The twenty-first session of the Conference of the Parties (COP22) recently that took place from 07 to 18 November 2016, in Marrakesh, Morocco has confirmed again the agreement from nearly 200 countries on the climate change (CC) issues in COP21. This agreement proved that climate change is still not a “heated topic of debate” (Raksakulthai, 2002) but now became a real risk for whole humanity. According to the Intergovernmental Panel on Climate Change (IPCC), climate change refers to ‘any change in climate over time, whether due to natural variability or as a result of human activity’ (IPCC 2007, p. 871). Climate change will lead to major impacts in the following sectors: water resources, agriculture, forestry, fishery, energy, transportation and health. (GFDRR, 2011) in which agriculture should be focus on due to its direct exposure to and dependence on weather and other natural conditions. The Third Assessment Report of IPCC 2007 concluded that climate change and variability will impact “*food, fiber and forests around the world due to the effects on plant growth and yield of elevated CO2, higher temperatures, altered precipitation and transpiration regimes, and increased frequency of extreme events, as well as modified weed, pest and pathogen pressure”.*

According to Foley et al (2005), until now 40% of the Earth’s land surface is accounted by cropland and pasture natural forests manage for 30% (3.9 billion ha) of the land surface with just 5% of the natural forest area providing 35% of global round wood. Moreover, in developing countries, nearly 70% of people live in rural areas where agriculture is the main income of livelihoods. In addition, growth in agricultural incomes in developing countries creates the demand for non-basic commodities and services to human development.

Obviously, adapting to climate change is an urgent action in agricultural sector. However, adaptation is an multipurpose action that involves decreasing risk and vulnerability, looking for opportunities, enhancing capacity of nations, regions, cities or private sector, communities, individual and natural system to deal with the impacts of climate change as well as mobilizing that capacity by implementing decisions and actions (Tompkins et al., 2010). It can be said that identifying adaption need is the most important in climate change adaption process and can help reduce risk and build capacity. IPCC 2014 has pointed out five kind of needs in climate change adaption process such as: biophysical and environmental needs, social needs, institutional needs, need for engagement of private sector and information, capacity and resource needs.

After identifying adaption needs, the next step of climate change adaption process is selecting adaption options. There are many different methods to categorize adaption options such as: by different sectors and stakeholders, by national, sectoral or local adaption plans, by structural, institutional and social options (Burton, 1996). However, adaption options are not always available to satisfy all adaption needs due to the constraints and limitations during the adaption process. Moreover, selecting adaption options can be influenced by the objective factors such as: rate, uncertain and cumulative effect of climate change (IPCC 2014). According to Berkhout et al (2006), policy and market condition may be “*stronger driver of behavior*” than climate itself. Hence, selecting adaption option rarely focuses on climate risks or opportunities alone. This selection should take in to account other goals such as: social benefit, poverty reductions or sustainable development. Decision making of adaption options requires the mobilization of knowledge, experiences of researchers, local authorities as well as local people. Adaptation to climate change requires decisions and action that are occurred by not only one individual but also from whole society. Making a decision of climate change adaption sometime is a complex process and requires the combination of multiple sectors. Hence, it is big challenge of choosing one adaption option that satisfies both effectiveness at rising resilience and social demands.

Consequently, selecting adaption options is a multi-attribute decision making that requires an effective decision support tool. In this paper, by considering three different tools, we recommend AHP -one method belonging to Multi-criteria analysis (MCA)- as an effective way in choosing climate change adaption. MCA provides one systematic way for decision makers to make sense of the wide range of information that may be relevant to making adaptation choices. MCA enables decision makers to create a structured framework for comparing a set of defined options across a number of diverse criteria so that they may evaluate adaptation options across a range of priorities or values (Aarjan Dixit 2012). According to (Van Ierland 2013) and (Aarjan Dixit 2012)MCA is high relevance for adaption and suitable for the case of comparing multi options for single problem. Especially, the criteria in MCA method can consist the uncertainty and intangible elements of a good adaption (Van Ierland 2013). Until now, MCA is w idely applied as decision support for climate change adaption such as: (Van Ierland 2013), (Aarjan Dixit 2012), (Stelios Grafakos 2012), (Bruin 2013), (Trærup 2015), (Noleppa 2013) and (Fischer 2011). MCA is considered the most proper method climate change adaption since climate change is a multidimensional problem and the adaptive methods affect many aspects of human life such as: economy, society or ecology. There are several ways to weight and prioritize the criteria and options such as: Multi-Attribute Utility Theory (MAUT), Analytical Hierarchy Process (AHP) and Outranking Methods. In our study, we will choose AHP method to conduct the MCA analysis. AHP is considered as an effective tool that can be used in decision-making process of climate change adaption. AHP allows consideration of both quantitative and qualitative data in the ranking of alternative options.

1. **Comparison of some decision-support techniques**

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| **Method** | **Description** | **Advantages** | **Disadvantages** |
| **Expert preferences technique** | *Delphi method:* was developed by Olaf Helmer, Norman Dalkey and Nicholas Rescher in the 50s. The Delphi method is based on structural surveys and makes use of the intuitive available information of the participants, who are mainly experts (Kerstin Cuhls).*SWOT method:* was developed from 1960 until 1970 by Marion Dosher, Ts. Otis Benepe, Albert Humphrey, Robert F.Stewart and Birger Lie. SWOT (strengths, weaknesses, opportunities and threats). This analysis can help you identify and understand key issues affecting your business, but it does not necessarily offer solutions.*Extrapolation method:* was firstly introduced by Thomas D. Clareson in 1959 in his book about science and fiction. Extrapolation may be understood as the extension of a data or process assuming that similar process would be applicable beyond the given data too. | * Big amount of quantity of information will be collected
* Limited the constraints of group working (for Delphi Method)
* Internal and external factors that are favorable and unfavorable to the objective's achievement.
* Valuable information about objective's chances can be gained by viewing each of the four elements of the SWOT analysis independently or in combination[[1]](#footnote-1)
* Quantitative and qualitative information from a number of sources be combined.
* Time and cost saving
 | * No mechanism to rank the significance of one factor versus another within any list. As a result, any one factor's true impact on the objective can't be determined.
* Significantly impact company performance, business decisions must be based on reliable, relevant and comparable data.
* The predicted objectives should be relatively stable
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| **Monetary valuation technique** | * Financial analysis: An assessment of the impact of an option on the decision-making organization’s own financial costs and revenues.
* Cost-effectiveness analysis: An assessment of the costs of alternative options which all achieve the same objective. The costs need not be restricted to purely financial ones.
* Cost-benefit analysis: An assessment of all the costs and benefits of alternative options.
 | * Assessing the alternatives under monetary valuation
* Can include non-cash opportunity costs and shadow prices for some marketed inputs
* Can take into account the willingness to pay or to accept for the public services
* Losses and gains of all member of the society can be outlined based on CBA
 | * The relevant data related to non-marketed impacts are not always available and might be too expensive to collect
* There are some impacts cannot quantified under monetary term.
* Can not take in to account the interactions among different impacts
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| **AHP technique** | “ *AHP is theory of relative measurement on absolute scales of both tangible and intangible criteria based on the judgment of knowledgeable and expert people and on existing measurement and statistics needed to make a decision*” (T. L. Saaty 1990). Hence, AHP not only formulates problem on a hierarchical basis but also considers various quantitative and qualitative criteria for the problem (Davood Samari 2012). AHP is based on four fundamentals: reciprocal judgments, homogenous elements, hierarchic or feedback dependent structure and rank order expectations. AHP describes relative judgment through pairwise comparisons to made qualitative term expressed numerically. Basically, AHP produces relative ratio scales measurement by converting from the set of objects on a standard scale through normalization. Finally, decisions are based on combining multidimensional scales of measurement into single “one-dimensional” scales of priorities. | * Combine quantitative and qualitative data, using monetary and non-monetary units, and can therefore consider a much wider set of criteria, even where quantification is challenging or limited.
* Be relatively simple and transparent, and can be done at relatively low cost and time saving.
* Expert judgment can be used very efficiently.
* It involves multi stakeholders and can be based on local knowledge as well as academic one
 | * Results need further interpretation and elaboration in more detailed studies.
* Different experts may have different opinions and will provide different scores, i.e. there is a degree of subjectivity involved.
* Stakeholders may have lack of knowledge and can miss important options.
* It may be difficult to give consistent scores to the alternatives.
* Analysis of uncertainty often highly qualitative.
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3. **AHP steps**

3.1 **Step 1: Identification criteria and sub-criteria**

This is actually the step of building hierarchical tree by identifying the main goal (problem), the criteria, sub-criteria and all alternatives. According to Saaty (1990), when creating a hierarchical tree, we should consider the following issues:

* Introduce the problem as in detail as possible but not so *thoroughly as to lose sensitivity to change in elements*
* Consider the environment around the problem
* Indicate the elements or attribute that involve to the solutions
* Identify the participants connected to the problem
* Hierarchical tree has descending structure from overall goal to criteria, sub-criteria and alternatives. According to (Saaty 1980), hierarchy is not a traditional decision tree for some reasons: each level of tree may present the different layer of problem such as: social, political and these level can be evaluated each other. Normally, global character will be presented at the higher level of tree and the specific ones will be introduced in the lower level.

**Graph 1: Hierarchical Tree**

*(Source: Author’s synthesis)*

**3.2 Step2: Pairwise comparison**

AHP technique uses pairwise comparison to derive relative scales by taking judgment or data from standard scale. The judgments are the results of pairwise comparisons. According to (Saaty 1980), one of advantages of pairwise comparison is allowing to focus judgment separately on each of several criteria or elements and do not concern others.

***Scales of measurement***

(Saaty 2008) developed scale (1: equal importance, 9: extreme importance) to evaluate the importance of criteria through pairwise comparison

**Table 1: Fundamental scale of absolute numbers**

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| --- | --- | --- |
| ***Intensity of importance***  | ***Definition***  | ***Explanation***  |
| 1 | Equal importance | Two activities contribute equally to the objective  |
| 2 | Weak or slight |  |
| 3 | Moderate importance  | Experience and judgement slightly favour one activity over another |
| 4 | Moderate plus |  |
| 5 | Strong importance  | Experience and judgement strongly favour on activity over another |
| 6 | Strong plus  |  |
| 7 | Very strong or demonstrated importance | An activity is favoured very strongly over another; its dominance demonstrated in pratice |
| 8 | Very, very strong |  |
| 9 | Extreme importance  | The evidence favouring one activity over another is the highest possible orfer of affirmation  |

*Source: How to make decision: The Analytic Hierarchy Process, Thomas L.Saaty ( 1980)*

**Table 2: Pairwise comparison matrix of three critieria**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Criteria**  | **Criteria 1** | **Criteria 2** | **Criteria 3** | **Eigenvector**  | **Weight** |
| **Criteria 1** | $$W\_{11}$$ | $$W\_{12}$$ | $$W\_{13}$$ | $$\left|W1\right|$$ | $$β\_{1}$$ |
| **Criteria 2** | $$\frac{1}{W\_{12}}$$ | $$W\_{22}$$ | $$W\_{23}$$ | $$\left|W2\right|$$ | $$β\_{2}$$ |
| **Criteria 3** | $$\frac{1}{W\_{13}}$$ | $$\frac{1}{W\_{23}}$$ | $$W\_{33}$$ | $$\left|W3\right|$$ | $$β\_{3}$$ |
| **Total**  | $$\sum\_{}^{}W\_{123}^{1}$$ | $$\sum\_{}^{}W\_{123}^{2}$$ | $$\sum\_{}^{}W\_{123}^{3}$$ | **1** | **1** |

*(Source: Le Thi Hoa Sen (2016))*

**Where:**

$\sum\_{}^{}W\_{123}^{1}$ **=** $W\_{11}$ **+** $\frac{1}{W\_{12}}$ **+** $\frac{1}{W\_{13}}$

$\left|W1\right|$ **=** ${W\_{11}}/{W\_{123}^{1}}$ **+** ${W\_{12}}/{W\_{123}^{2}}$ **+** ${W\_{13}}/{W\_{123}^{3}}$

$\left|W2\right|$ **=** ${W\_{123}^{1}}/{W\_{12}}$ **+** ${W\_{22}}/{W\_{123}^{2}}$ **+** ${W\_{23}}/{W\_{123}^{3}}$

$\left|W3\right|$ **=** ${W\_{123}^{1}}/{W\_{13}}$ **+** ${W\_{123}^{2}}/{W\_{23}}$ **+** ${W\_{33}}/{W\_{123}^{3}}$

$β\_{1}$ **=** $\frac{1}{3}$$\left|W1\right|$$β\_{2}$ **=** $\frac{1}{3}$$\left|W2\right|$$β\_{3}$ **=** $\frac{1}{3}$$\left|W3\right|$

**3.3 Step 3:** Aggregation of the priorities to have a ranking of the alternatives was carried out. This was done by determining the ratings of the alternatives with respect to each criterion and then adding up these ratings for all criteria. Calculate similar way with sub-criteria of each criterion, we have weight of each sub-criteria ($γ\_{i}$) as following table

**Table 3: Weight of each sub-criterion**

|  |  |  |
| --- | --- | --- |
| **Criteria** | **Sub-criteria** | **Priorities** |
| Criteria 1 ($β\_{1})$ | Sub-criteria 11 ($γ\_{1}$) | $$δ\_{1}$$ |
| Sub-criteria 12 ($γ\_{2}$) | $$δ\_{2}$$ |
| Sub-criteria 13 ($γ\_{3}$) | $$δ\_{3}$$ |
| Criteria 2 ($β\_{2}$) | Sub-criteria 21 ($γ\_{4}$) | $$δ\_{4}$$ |
| Sub-criteria 22 ($γ\_{5}$) | $$δ\_{5}$$ |
| Sub-criteria 23 ($γ\_{6}$) | $$δ\_{6}$$ |
| Criteria 3 ($β\_{3}$) | Sub-criteria 31 ($γ\_{7}$) | $$δ\_{7}$$ |
| Sub-criteria 32 ($γ\_{8}$) | $$δ\_{8}$$ |
| Sub-criteria 33 ($γ\_{9}$) | $$δ\_{9}$$ |

*(Source: Le Thi Hoa Sen (2016))*

Where:

**Priorities (**$δ\_{i}$**) =** $β\_{i}$ **\*** $γ\_{i}$

* **Identify rating point of each sub criteria by following formula**

$P\_{ni}$ **=** $a\_{ni}$ **\*** $δ\_{ni}$

 Where: $P\_{ni}$: Rating point of alternative n for the sub-criteria i

 $a\_{ni}$: Assessing point of sub criteria i of alternative n (based on Likert scale)

 $δ\_{ni}$: Priorities of sub criteria i

$P\_{n}$ **=** $\sum\_{i=1}^{n}P\_{ni} $

 Where: $P\_{n}$: Total point of alternative n

 $P\_{ni}$: Rating point of alternative n for the sub-criteria i

**3.4 Step 4:** Control of consistency was done by determining the consistency index, CI that is calculated as follows:

**CI =** $\frac{λ\_{max }-n}{n-1}$

Where: $λ\_{max }$**:** the eigenvalue of the matrix

 n : the size of the matrix

A consistency index of up to 10% is tolerable (T. L. Saaty 1990). A slight deviation of the consistency index from 10% is not a problem. A large deviation means that the judgments are not optimal and have to be improved

1. ***Reviewing related studies***

Regarding to Expert preferences technique,Delphi method has been applied in identifying the successful adaption to climate change through an iterative process, expert respondents coalesced around a definition based on risk and vulnerability and agreed that a transparent and acceptable definition should reflect impacts on sustainability. According to the final definition, agreed by the Delphi panel, successful adaptation is any adjustment that reduces the risks associated with climate change, or vulnerability to climate change impacts, to a predetermined level, without compromisingeconomic, social, and environmental sustainability. (Doria, et al. 2009). However all participants agreed that the checklist criteria should be weighted, most refused to attribute weights, for various reasons. Many participants considered that the relative importance of specific criteria depends on the particular case to which the criteria are applied.

SWOT method is applied to evaluate the perception of Rwandan government officials, NGOs, and extension specialists about smallholder agroforestry adoption as a strategy for smallholder farmers in Rwanda. Due to limitations in human judgment and differing view points among group participants absolute consistency is not expected. Hence after using SWOT, Pair-wise comparisons are conducted separately for all factors within a category and a priority value for each factor is computed using the eigenvalue method.(Stainback, et al. 2011).

CBA is used to evaluating global climate policy by sketching and analyzing the welfare foundations of cost-benefit analysis and from this perspective analyses the role of cost-benefit analysis in the climate policy debate, particularly with reference to intergenerational effects (Lind 1995). However, this method raised the problem of discount future that can bias against future generation.

Based on the advantages of AHP that have been analyzed above , It seems that AHP can solve the problems of these above method. AHP has been applied in many fields such as: education, marketing, environment or agriculture. In this paper, we just focus reviewing the study related to agricultural and climate change adaption field.

Monica Huehner et al (2016) have applied AHP in assessing Agri-environmental measures (ARM) of the Rural Development Program in Slovenia. In this paper, authors have identified three main criteria to evaluate one ARM including: Social acceptability, Environmental reliability and Economic feasibility. For each criterion, authors have built the sub-criteria to evaluate 23 alternatives. Thank to AHP’s result, paper concluded that organic fruit, vine and horticultural production are seen as the most important AEM in the case of Slovenia.

 (N. Van Cauwenbergh 2007) have successfully applied AHP in assessing the sustainability of agricultural systems. The principles, criteria and indicators have been identified to evaluate the sustainability of agricultural system in the context of Sustainability Assessment of Farming and the Environment (SAFE). SAFE starts from defining sustainability as maintaining or enhancing the environmental, economic and social functions of an agro-ecosystem as formulated in a set of principles and criteria. Environmental principles are derived by considering in a systematic way the quantity, quality and fluxes of all natural resources. Social and economic principles rest on present-day societal values and concerns. The proposed analytical framework is not intended to find a common solution for sustainability in agriculture as a whole, but to serve as an assessment tool for the identification, the development and policies.

Applying AHP in different aspect of agriculture, Ni and Li (2003) also used this method to evaluate soil erosion in term of land-use structure changes in the case study of Zhifanggou Watershed in Ansai, Shaanxi Province, China. In this paper, authors have identified the degree of impact of different level of land use through pairwise comparison matrix. The outcome of AHP process is the land-use Structure Characteristic Index (SI) that can reflect the resulting impact of human factors and serve as an indirect measure of soil erosion variation. However, according to authors, AHP has some limitations such as: subjective judgment, degree of uncertainty...

In the case of Viet Nam, Thi Xuan My Tran et al (2017) have applied AHP to prioritize irrigation asset renewals in the case of La Khe irrigation scheme, Vietnam. In this study, assets were of four different types, canals, structures, off takes and pumps. The next level comprises the three major factors that affect the performance of assets: hydraulic performance HP), condition 0) and importance I). The lowest level are the criteria associated with each factor for each particular type of asset. After calculating the importance judgment, relative weightings of each asset type and asset scoring, authors prioritized the renewals by location of asset and of asset types.

In term of climate change adaption, Oz Sahin et al (2014) has used AHP to evaluate the sea level rise adaption options under approach involving stakeholders in the case of Goal Coast, Australia. In this paper, authors have built five criteria to assess an adaption options for reducing vulnerability to sea level rise including: applicability, effectiveness, sustainability, flexibility and cost. In addition, five alternatives have been identified namely: Planned retreat, improve building design, improve public awareness, built protective structure and take no actions. Moreover, paper also invests the stakeholders’ opinions for adaptation alternative including: politician, experts and residents. AHP’s results show that in the case of Australia, effectiveness and sustainability are the most importance criteria for one adaption option while cost is not major problem. Applicability and flexibility of the adaption alternatives are of medium importance.

In study on selecting the climate change adaption methods for the coastal region of Phu Vang district, Thua Thien Hue province, Sen (2016) has successfully applied AHP techniques in finding the most suitable adaptive methods for the study are. In this research, firstly, the alternative options that have been successfully applied in other areas of Vietnam would be used as references. Secondly, the criteria that would be used to assess the adaptive options have been identified based on the characteristics of study are in terms of society, economy and ecology. The criteria of level one include the coherence, the effectiveness, the resistance and the sustainability. In each criterion, there are many sub-criteria that would be not the same for the different study areas. Finally, AHP has been conducted to weighting the criteria through group focus discussion and key informants interviews. Author has classified the adaptive methods into three groups: agriculture, husbandry and aquaculture. Results show that for the case study of Phu Vang district, the resistance ranks the lowest priority when farmers considering an adaptive option. In terms of final point, agriculture has highest points (4.475) and aquaculture has lowest point (3.789). In agriculture group, planting bitter loopah at the wrong season is highly recommended. In the aquaculture group, solution of feeding eal got the lowest point. Thank to AHP techniques, research found the proper climate change adaptive methods that satisfy multi- attribute purposes and will be feasible to apply in practice in case of Thua Thien Hue province.

1. ***Conclusion***

 As the conclusion of COP22, climate change adaption now is the concern of not only one individual but also of whole society. Since climate change issue is a multidimensional problem, it is needed a mobilization of knowledge, experiences of researchers, local authorities as well as local people in selecting an adaption option. Moreover, decision making in climate change adaption is the complex process of selecting from many alternative based on various criteria. Hence, MCA in general and AHP in particular are considered as an effective tool to overcome the challenges of selection one adaption option. We can not deny the advantages of AHP such as: can quantify the qualitative criteria, flexibility in applying and integrating with different techniques (Vaidya and Kumar, 2006), diversifying the source of data collection, considering multi sector and stakeholders in group working when selecting one adaption option (Kasperczyk and Knickel, 2005)Thank to these advantages, AHP techniques can compensate the disadvantages of other techniques such as: expert preferences or monetary valuation techniques. However, this method still consists some limitations namely: highly requiring exact calculation, the objective opinions from experts might influence the research’s results, the researchers should have experience and skills in implementing AHP. Despite of the limitations, AHP still outstanding method in helping the policy makers decide which adaption method can help farmers to cope with climate change.

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